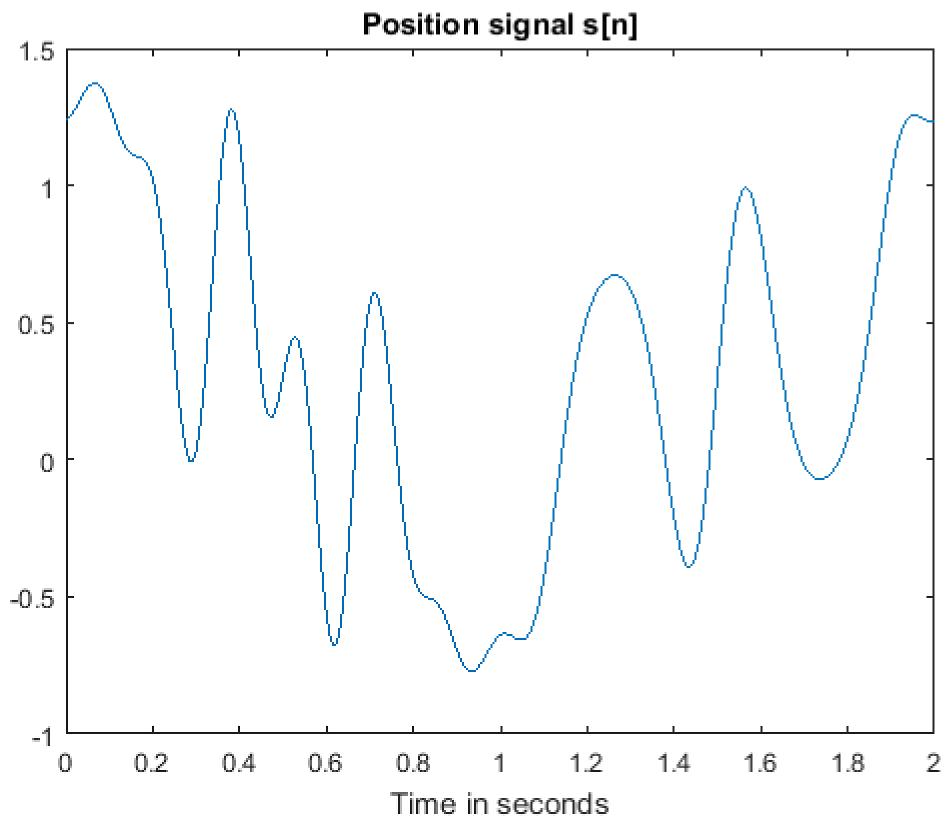
ELEC 403 Lab 3 Script - EXPERIMENT 3

DESIGN OF A BAND-LIMITED DIFFRERENTIATOR FOR VELOCITY ESTIMATION BASED ON NOISY POSITION DATA % This script is used to fulfill the requirements in the lab manual. %

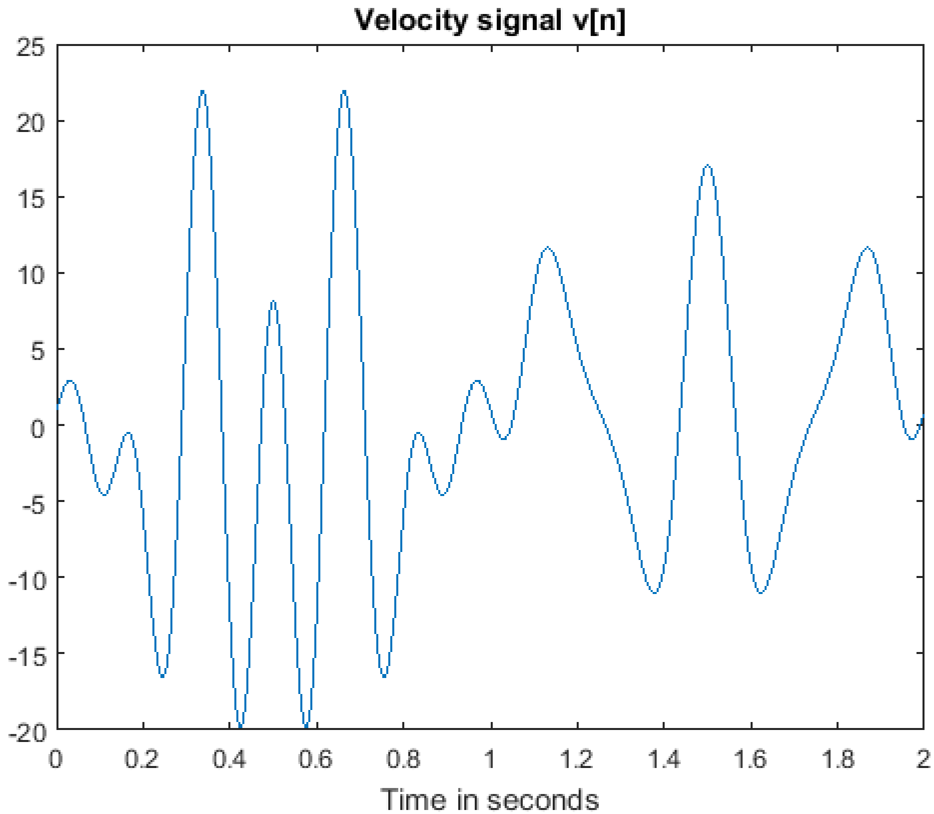
3.6.1 - following Sec. 3.3 to generate noise-free position signal s[n] and v[n]

```
close all
clear all

t = 0:1/512:(2-1/512);
t = t(:);
randn('state', 7)
a = 0.25*randn(7,1);
randn('state', 19)
b = 0.25*randn(7,1);
s = 0.3*ones(1024,1);
v = zeros(1024,1);
for i = 1:7,
 s1 = a(i)*sin(2*pi*i*t);
 s2 = b(i)*cos(2*pi*(i-0.5)*t);
 s = s + s1 + s2;
 v1 = i*a(i)*cos(2*pi*i*t);
 v2 = (i-0.5)*b(i)*sin(2*pi*(i-0.5)*t);
 v = v + 2*pi*(v1 - v2);
end
figure
plot (t,s)
xlabel('Time in seconds')
title('Position signal s[n]')
print('Reproduced3_1a','-dpng','-r300')
figure
plot (t,v)
xlabel('Time in seconds')
title('Velocity signal v[n]')
print('Reproduced3_1b','-dpng','-r300')
```



Position signal s[n]
1.5
1
0.5
0
-0.5
-1
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time in seconds



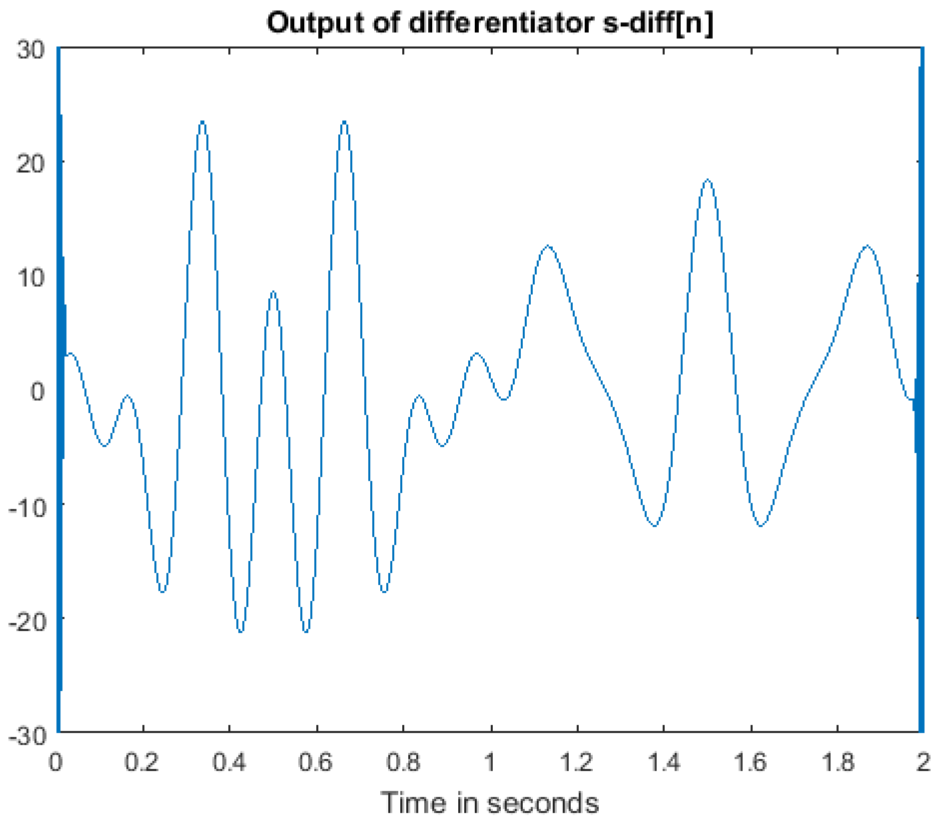
3.6.2 - get a conventional differentiator of length 23 by following Sec. 3.3

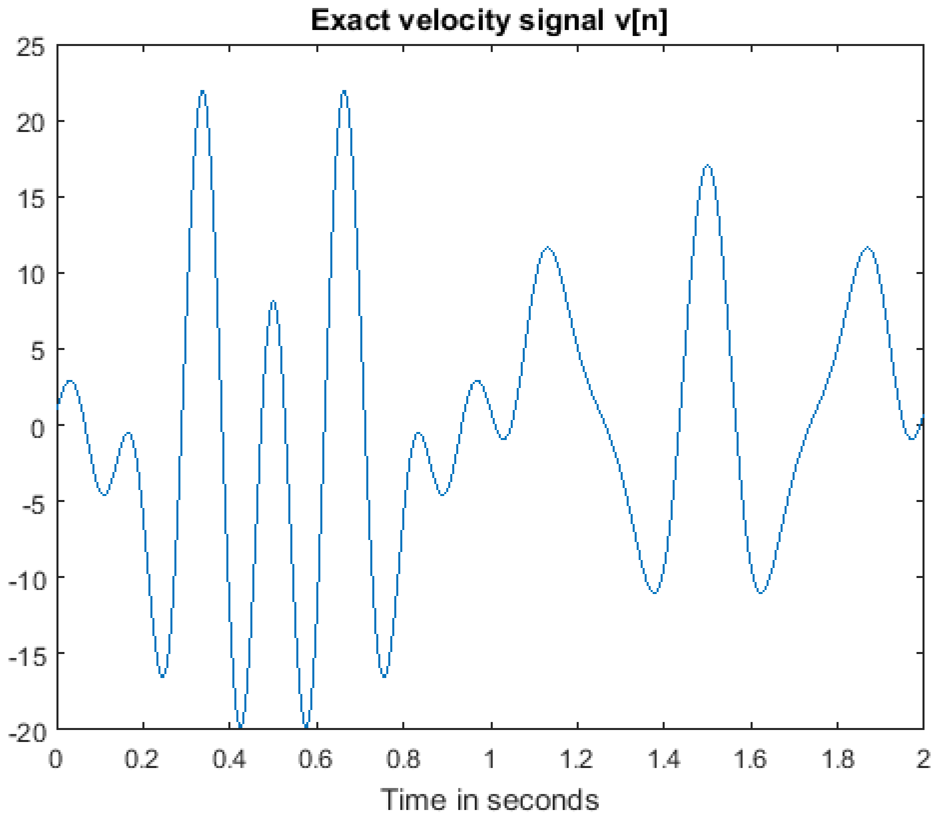
```
fs = 512;
Ts = 1/fs;
N = 23;
M = (N-1)/2;
n = 1:1:M;
h = cos(n*pi)./(Ts*n); % compute desired impulse response using (3.5)
h = [-fliplr(h) 0 h]; % compute desired impulse response using (3.4)
win = hamming(N); % construct 41-point Hamming window
h_diff = win(:).*h(:); % generate the impulse response of the differentiator

% We now apply the differentiator to the position signal s[n] by discrete convolution:
sw = conv(h_diff, s); % perform digital differentiation by discrete convolution
s_diff = sw(12:1035); % reduce the output length to 1024

figure
plot (t, s_diff)
title('Output of differentiator s-diff[n]')
xlabel('Time in seconds')
axis([0 2 -30 30])
print('Reproduced3_2a','-dpng','-r300')
```

```
figure
plot(t,v)
title('Exact velocity signal v[n]')
xlabel('Time in seconds')
print('Reproduced3_2b','-dpng','-r300')
```





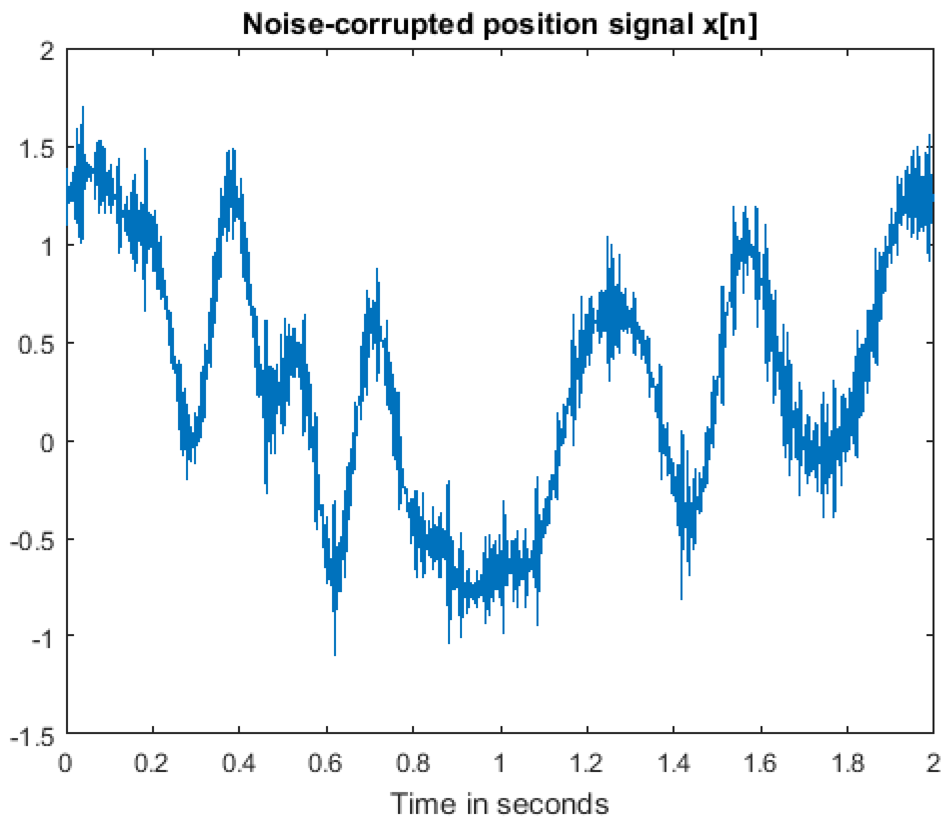
3.6.3 - generate noise w[n] and noise-corrupted position signal x[n]

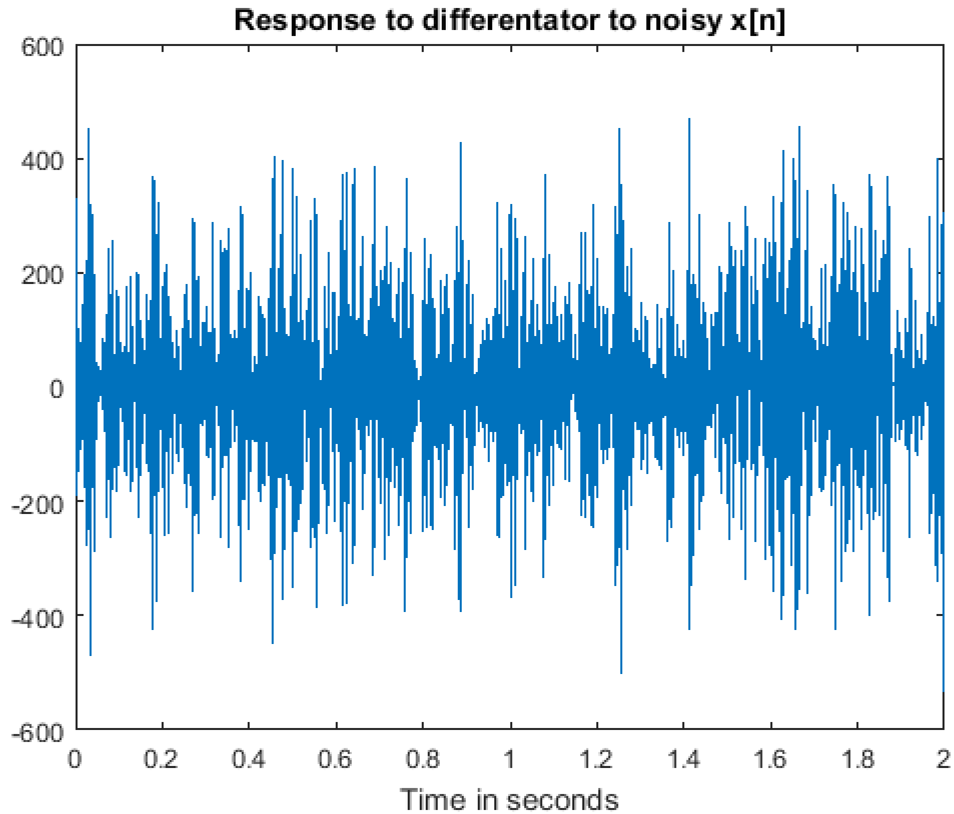
```
randn('state',9); % sets a seed state for generating a random sequence
w0 = randn(1024,1); % generate 1024 Gaussian white random samples
mw = mean(w0); % evaluate its mean value
w0 = w0 - mw; % modify w0 to have a zero-mean
c = 0.3/sqrt((w0'*w0)/1024);
w0 = c*w0; % modify w0 to have a standard deviation = 0.3
h = fir1(250,0.7,'high'); % get a good highpass FIR filter with cutoff freq. = 0.7
w1 = conv(h,w0); % apply highpass filtering to the white sequence
w = w1(126:1149); % cut the filtered sequence to a right size
w = w(:); % make sure w[n] is a column vector
x = s + w; % Generate noisy position signal

figure
plot(t,x)
title('Noise-corrupted position signal x[n]')
xlabel('Time in seconds')
print('Reproduced3_3a','-dpng','-r300')

figure
sww = conv(h_diff, x); % perform digital differentiation by discrete convolution
w_diff = sww(12:1035); % reduce the output length to 1024
```

```
plot(t,w_diff)
title('Response to differentator to noisy x[n]')
xlabel('Time in seconds')
print('Reproduced3_3b','-dpng','-r300')
```





3.6.4 - design BLD with N =23, wp = 0.2pi, wa=0.5pi and Ts = 1/512

```
format long
h_BLD = lab3_363(23,1/512,0.2*pi,0.5*pi);
h_BLD
```

```
p =

  Columns 1 through 3

  40.686020377278155  72.029997840609937  87.241378322871554

  Columns 4 through 6

  83.874163751577640  64.339814440168666  35.017056807228130

  Columns 7 through 9

   4.263870745255236 -20.034761157085999 -32.633158103349196

  Columns 10 through 11
```

```
 -32.169957942439694 -21.172824565516400


q =

  Columns 1 through 3

   0.861793301924978  -0.531283440388385   0.164290969791942
  -0.531283440388385   1.026084269608764  -0.106107378607646
   0.164290969791942  -0.106107378607646   1.148539524585688
   0.425176062996481   0.286746224868288  -0.209603359847701
   0.122455220840790   0.321680099301193   0.297205127125491
  -0.103495957773908   0.132914183847191   0.413386424691162
   0.010458873370765  -0.011789685918372   0.073473169617056
   0.091706249068981  -0.048982091017164  -0.172172019577499
  -0.059441055005861  -0.068676020848451  -0.088609561706681
  -0.160382437396598  -0.099068396605395   0.005378476006910
  -0.039627312563967  -0.086327839719034  -0.080431475586132

  Columns 4 through 6

   0.425176062996481   0.122455220840790  -0.103495957773908
   0.286746224868288   0.321680099301193   0.132914183847191
  -0.209603359847701   0.297205127125491   0.413386424691162
   1.158998426828271  -0.117897034238076   0.237764142189861
  -0.117897034238076   1.099557441874591  -0.278279393929659
   0.237764142189861  -0.278279393929659   1.059930072001250
   0.253004065922314   0.198136772316520  -0.204224976940981
   0.033845799793747   0.327058482948997   0.216771753913668
  -0.098117571193358   0.052480781412049   0.291842721359883
  -0.069974479303084  -0.133333347142564   0.091841416993021
  -0.029837425590578  -0.030613843501887  -0.042616003903041

  Columns 7 through 9

   0.010458873370765   0.091706249068981  -0.059441055005861
  -0.011789685918372  -0.048982091017164  -0.068676020848451
   0.073473169617056  -0.172172019577499  -0.088609561706681
   0.253004065922314   0.033845799793747  -0.098117571193358
   0.198136772316520   0.327058482948997   0.052480781412049
  -0.204224976940981   0.216771753913668   0.291842721359883
   1.078565053597575  -0.239440720914006   0.256132389528398
  -0.239440720914006   1.117925689211494  -0.148723378027174
   0.256132389528398  -0.148723378027174   1.125975706841395
   0.382560081830462   0.264182407158481  -0.216955130677360
   0.099891434609813   0.314328329220408   0.237764147283939

  Columns 10 through 11

  -0.160382437396598  -0.039627312563967
```

```
  -0.099068396605395  -0.086327839719034
   0.005378476006910  -0.080431475586132
  -0.069974479303084  -0.029837425590578
  -0.133333347142564  -0.030613843501887
   0.091841416993021  -0.042616003903041
   0.382560081830462   0.099891434609813
   0.264182407158481   0.314328329220408
  -0.216955130677360   0.237764147283939
   1.099557446966611  -0.196292831636055
  -0.196292831636055   1.077942522550796


h_BLD =

  -0.797923862820184
  -0.676208173791139
   2.375172129586918
   5.611656469894399
   1.165735106609191
 -12.499355678469954
 -19.819051269390684
   0.643297572310985
  46.809278069707453
  81.820406520359597
  65.510591958352848
                   0
 -65.510591958352848
 -81.820406520359597
 -46.809278069707453
  -0.643297572310985
  19.819051269390684
  12.499355678469954
  -1.165735106609191
  -5.611656469894399
  -2.375172129586918
   0.676208173791139
   0.797923862820184
```

3.6.5 - apply BLD designed in 3.6.4 to x[n] save figures.

```
xx = conv(h_BLD, x); % perform digital differentiation by discrete convolution
x_diff = xx(12:1035); % reduce the output length to 1024
figure
plot(t,x_diff);
axis([0 2 -30 30])
title('Applied BLD to noisy x[n]')
xlabel('Time in seconds')
print('Pic3_5','-dpng','-r300')
```

```
figure
sssx = conv(h_BLD, s);
sss_diff = sssx(12:1035);
plot(t,sss_diff);
axis([0 2 -30 30])
xlabel('Time in seconds')
title('Applied BLD to s[n]')
print('Pic3_5b','-dpng','-r300');
```